Guest Editorial

Gold as a Key Element for Green Nanotechnology

The Science and Technology Committee of the Japanese government has selected four areas of technology within which the most important research targets for the 21st century will be defined: information technology, biotechnology, environmental technology and nanotechnology (materials, devices and machines). The International Conference on Catalytic Gold held in Cape Town in April (see page 56 of this Issue) inspired confidence in my expectation that gold will find a unique role in these four major technologies. Gold has five characteristic features which make it unique: high chemical and thermal stability, mechanical softness, high electrical conductivity, and beautiful appearance; and combinations of these attributes will give rise to many relevant applications.

Innovations required for information technology in the near future will be highly integrated electronic devices, designed and fabricated on the nanometre (nm) scale: gold is an indispensable element for nanoscale electronic devices because it is resistant to oxidation and mechanically robust. At the same time photonics is replacing electronics for communication of large amounts of data. The well known elegant red colour in Venetian crystal glass arises from surface plasmon absorption of blue light by gold nanoparticles a few tens of nm in size. Gold nanoparticles embedded in glass materials are currently being investigated for non-linear optics. Arrays of quantum dots of metals and suitable organic molecules self-assembled on the surface of gold have unique electronic properties, with potential applications as molecular computers.

Within the area of biotechnology, gold compounds have already been used successfully for the treatment of rheumatoid arthritis. In Japan we often put thin gold foils into Japanese tea, sake and food. For example, in our New Year celebrations we enjoy sake containing gold foils. We believe that gold is not only harmless but also helps to improve our health. We have no scientific explanation for this but believe that further investigations of the use of metallic gold and its compounds will lead to more applications in medical science.

The most important requirements for environmental technology are that the methods used should be energy efficient and conserve resources. Consequently, for control of water and air purity, the use of heterogeneous catalysts operating at ambient temperatures is an attractive approach. Gold is an outstanding element for use here because it is catalytically active at low temperatures: the adsorption of molecules can take place on step, edge and corner sites of the surfaces, with moderate binding energies at room temperature. Gold catalysts perform best within the temperature range 200 - 350 K, whereas the best range for palladium and platinum is *ca* 400 - 800 K.

There are three major challenges for heterogeneous catalysis R&D: water splitting into hydrogen and oxygen, nitric oxide decomposition into nitrogen and oxygen, and direct methanol synthesis from methane. NO decomposition is thermodynamically favourable at temperatures below 1000 K and using an appropriate catalyst, the reaction can take place without consuming energy. The most serious constraint with catalysts tried for this reaction to date is that their surfaces become passivated by the accumulation of oxygen species formed from the dissociation of N-O bonds. Since gold has a poor affinity for oxygen species, catalysts based on gold may not deactivate in this manner. It is envisaged that in order to accomplish this important objective heterogeneous gold catalysts will need to have nm dimensions, rather than the micrometre (μm) dimensions currently used in electronic circuits. The reaction should be monitored and the surface conditions controlled using electrical, magnetic or photonic systems.

Overall, environmental technology will be developed using nanotechnology as an important component. This trend can be regarded as Green Nanotechnology, within which gold will surely be one of the most important elements. The emission of gold into the environment is not only without hazard, but it may also help to improve human health! The extreme chemical inertness of gold may make its recyling easier than for other metals. This type of element is therefore ideal for use in the 21st century! What other element can meet all these objectives as well as gold does?

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